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(54) **Base stations for mobile telephones**

(57) A mobile cellular telephone system including a personal or mobile terminal 10 for communicating with a base station 14 and a plurality of local access base stations (LABS) 2 for detecting transmission from the personal or mobile terminal and relaying the transmissions in an uplink path to the base station, wherein the plurality of LABS are so positioned in relation to a designated area in order that each LABS can detect transmissions from the terminal within the designated area in order to provide diverse paths for relaying detected transmissions to the base station.

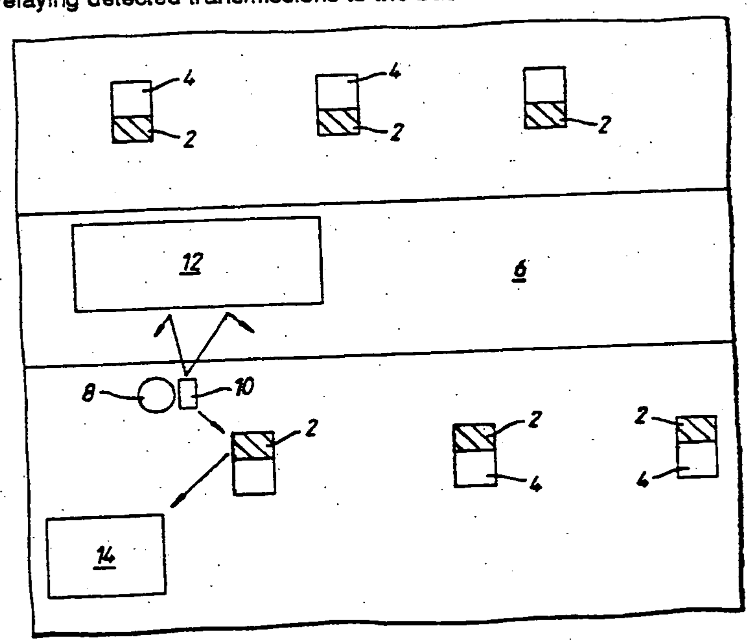

Fig.1.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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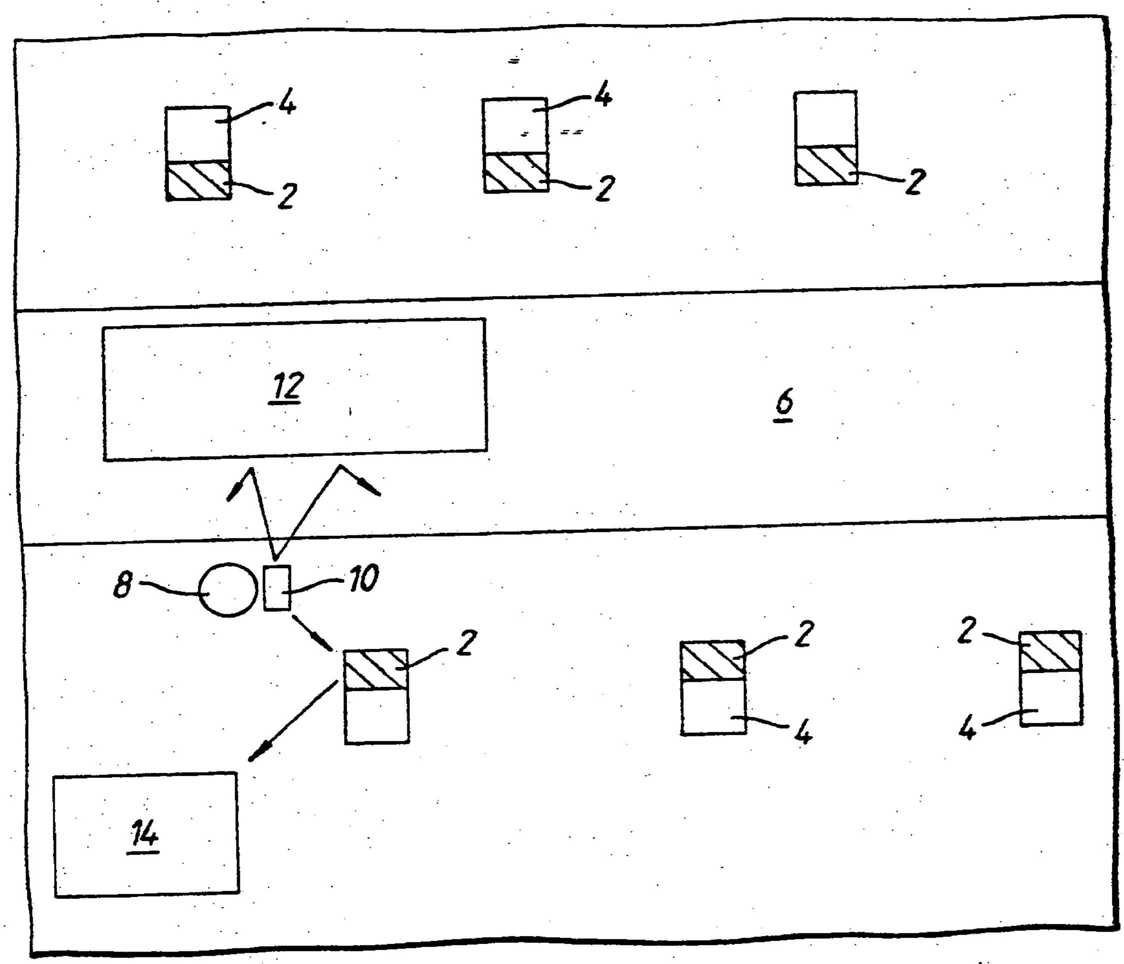
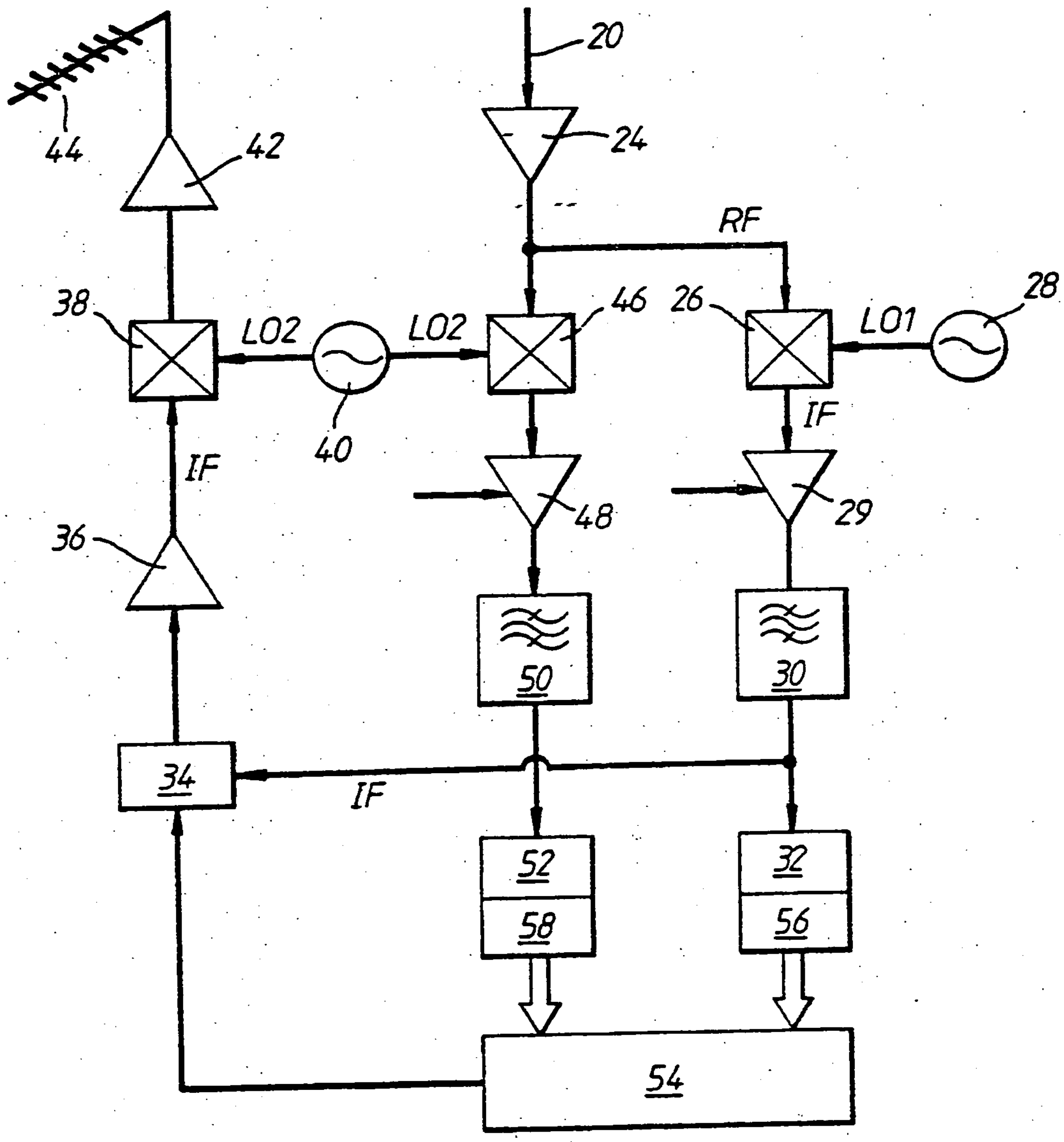


Fig.1.



20
24
44
42
RF
38
LO2
LO2
46
26
LO1
28
40
IF
IF
36
48
29
50
30
34
IF
52
58
32
56
54

Fig.2.

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BASE STATIONS FOR MOBILE TELEPHONES

Field of the Invention

This invention relates to base stations employed in mobile telephone systems having a cellular network, particularly though not exclusively the GSM (Groupe Speciale Mobile) digital cellular network intended for pan-European operation.

Background Art

The GSM digital cellular network has a closely defined and well known implementation. It operates on a time domain multiple access to a channel frequency, wherein traffic frames of eight channels or time slots (each 50μs long) are provided, each channel being assigned to a respective mobile station.

Originally intended for mobile telephones in motor cars, increasing interest in being placed in mobile stations for personal use by an individual, whether at home, at work or travelling.

Personal radio telephone terminals are constrained by reasons of both size weight and health and safety regulations to maximum transmitter power of the order of 100 mW mean.

In areas of low subscriber density (rural and some suburban), offered traffic will be sufficiently low to justify the installation of high power, long range (macro) base stations only: these must then serve the mixed mobile and portable user communities planned for the future. Macro base stations (MBS), and mobile stations (MS) typically employ matched transmit powers of 20 watts. However, when these same MBS are required to communicate with low power,

personal stations (PS), a fundamental asymmetry in path loss capability (of around 23 dB) will be created due to the different transmitter powers available in the 2 way radio path between MBS and PS.

It has been proposed to remove this asymmetry by introducing gain into the up-link path (i.e. the path from the mobile to the base station) by providing local access base stations (LABS). Such LABS comprise a low cost, radio repeater unit which, in a Static LABS configuration, will be sited well above road level in, say, a street lamp. Therefore, the up-link signal level will be enhanced not only by the repeater gain but also by the reduced path loss resulting from the more nearly line-of-sight communications over the tandem PS to LABS and LABS to MBS radio paths.

Despite introducing significant improvements in up-link signal gain, problems may still occur particularly in urban areas where the line of sight path between PS and LABS is blocked temporarily e.g. by a moving bus or lorry.

Summary of the Invention

It is an object of the present invention to provide a reliable high-gain up-link path between a mobile or personal station and a base station in a cellular mobile telephone network.

The concept of the present invention is to introduce space diversity into the LABS whereby should one signal path be blocked between a mobile or personal station (hereinafter termed P/MS) and a local access base station (LABS), at least one other path will be available which will on average not be blocked.

If in accordance with the invention LABS are spaced sufficiently closely that a P/MS can communicate, on average, with three LABS simultaneously, then additional significant gain can be introduced by utilising the diverse radio paths that are available. Propagation modelling studies indicate that the use of triple diversity techniques at radio frequencies around 1800 MHz provide effective path loss enhancements of up to 20 dB in a 6 dB mean shadow fading (urban) environment for low outage coverage. In these situations, LABS may also be used to repeat the down-link signal to maximise two-way cell coverage.

From the preceding, LABS according to the present invention offer the following advantages:-

* Allow two-way communication coverage between PS and MBS to be more nearly balanced.
* Provide very much improved local coverage particularly in otherwise intractable propagation black spots.
* Permit PS power, and thus size and weight, to be minimised.
* Enable MBS spacings to be increased, thus reducing infrastructure costs.

LABS may also take other configurations. For example, they may be located within private cars to provide an owner with PCN access when roaming within a hundred metres or so from his car. Equally, when on the move, these Mobile LABS will serve to provide on-the-move communications for the driver.

The LABS repeater gain will normally be of the order of 125 dB in practice. In principle, this gain may be realised using wideband or narrowband, on-channel or F1/F2 repeater configurations.

Wideband repeaters are not preferred on grounds of inadequate sensitivity and, on-channel repeaters are not preferred due to their technical risk of input and output signals on the same frequency. The narrowband F1/F2 repeater is the preferred configuration, in which the incoming signal has a carrier frequency F1 and the outgoing signal a carrier frequency F2.

Preferred features of LABS performance are:-

* They should not rebroadcast noisy signals (at high level) when exposed to low level, noisy signals at their input.
* They should support automatic power control procedures to ensure correct operation of the MBS receivers and to minimise PS power consumption.
* They should provide 3 path diversity operation.

LABS may be realised using either of two extreme approaches. At one extreme, LABS may take the form of a sophisticated unit that incorporates sufficient "intelligence" to exploit fully all potentially available performance features while preserving full compatibility with the current GSM specification. At the other extreme, LABS could comprise a minimal functionality, transparent repeater with minimum manufacturing cost taken as the predominant design criterion.

Realisation of the sophisticated LABS infrastructure is complicated by:-

* The use of power control signalling data that is encrypted at the MBS, so that it is unavailable at the LABS unless equipped with decryption facilities.
* In a situation where a plurality of LABS are simultaneously feeding a single PS channel to an MBS, inevitable frequency differences between the reference frequency sources of the LABS (required to realise branch micro/macro combining), which will cause carrier beats and consequent excessive phase changes for the GSM demodulation/equaliser combination at the MBS.
* Contending PC commands at a PS when operating at widely differing ranges from the three LABS required to implement micro/macro diversity working.
* Difficulties in maintaining precise squelch lift thresholds in the LABS uplink receiver (-104 dBm) to prevent the rebroadcast of noise or noise-corrupted signals. Note that accurate signal level measurement involves signal envelope integration, which, in turn, involves significant message time delay. This measurement will also be required to cater for the possibility of unscheduled half rate and DTX transmissions.

The majority of these complexities may be overcome by the adoption of a simple, transparent repeater that incorporates the features below:-

* Macro-diversity combining by selection of a single LABS providing the up-link path. Such LABS would be selected on the basis of providing the best or a sufficient SNR.
* LABS initiated simple, automatic PC (power control) on both LABS to MBS and LABS to PS links based on measurement of received signal level.
* The use of generous squelch lift thresholds at the LABS uplink receiver to accommodate all possible extreme effects of receiver temperature, ageing, etc. Typically, it is assumed that a squelch lift threshold of -95 dBm would provide such a margin.

The adoption of a single LABS selection scheme to enhance up link path loss capability precludes use of this approach to enhance the reciprocal down link path since total, continuous coverage must be provided throughout the MBS service area for down link (BCCH) control channel transmissions. Therefore, in this situation, multiple LABS operation on the down link path would be required to ensure complete coverage, which would inevitably lead to regions of overlapping signals with consequent creation of carrier beats due to carrier frequency differences between LABS.

Although, in principle, selection of a single, optimally sited LAB to realise macro-diversity working is best controlled by the MBS, this involves an additional signalling load for the GSM channel. Therefore, a procedure that could be implemented by either the LABS or PS themselves is preferred. Candidate approaches are:-

* Use of a deployment where adjacent LABS operate on different carrier frequencies. The complete LABS cluster frequency allocation of 4 carriers would be allocated between adjacent LABS on a grid repeat pattern. The PS would search over the 4 carriers and select the strongest. This operation is analogous to the Dynamic channel Allocation (DCA) feature of the DECT protocol.
* The use of an additional receiver in LABS to monitor the presence of transmissions from adjacent LABS back to the MBS. LABS would be programmed to switch on and rebroadcast a local PS transmission dependent on received PS signal strength, and on the presence of transmissions on that carrier frequency and time slot from adjacent LABS. In order to eliminate the possibility of two LABS switching on simultaneously to rebroadcast transmissions from the same PS, LABS would also incorporate a pre-determined time delay, allocated on, say, a 9 element grid pattern, prior to initiating switch-on. (c.f. the ALOHA protocol).

Of the above approaches, that involving the assignment of different carrier frequencies to adjacent LABS involves modification of the GSM PS specification to provide fast handover. It also involves reduction of the re-use distance between LABS from one macrocell (assuming a 4 cell cluster size) to two LAB spacings, which would necessarily require increased spectrum allocation. In contrast, the approach involving use of an additional monitor receiver in the LABS

does not involve any change to the GSM specification and no increased spectrum allocation. Therefore, this configuration is recommended.

Brief Description of the Drawings

A preferred embodiment of the invention will now be described with reference to the accompanying drawings wherein:-

Figure 1 is a schematic view of a group of LABS in accordance with the invention offering multipath diversity to a PS mobile; and,

Figure 2 is a block diagram of a LABS in accordance with the invention.

Description of the Preferred Embodiment

Referring to Figure 1 this shows a configuration of LABS in accordance with the invention wherein each LABS 2 is mounted in the head portion of a lamp standard 4, the lamp standards being disposed along opposite sides of an urban street 6. A pedestrian 8 carries a personal station (PS) 10. A bus 12 is indicating passing along the street. LABS 2 are arranged to communicate with a macro base station (MBS) 14.

The available transmission power for PS 10 is about 100mW, and LABS 2 are positioned sufficiently closely that three LABS 2NN1, 2NN2, 2NN3 forming the nearest neighbours to PS 10 have sufficient sensitivity to correctly receive GSM transmissions from PS 10. As shown, bus 12 prevents direct transmission to the LABS on the opposite side of the street and in this situation LABS 2NN1 is the sole

LABS able to pick up the signal which it thereupon transmits in a line of sight path to MBS 14.

Referring to Figure 2 there is shown a block circuit diagram of a LABS in accordance with the invention comprising an antenna 20 comprising an omnidirectional invented monopole coupled to an RF pre-amplifier 24 followed by a mixer 26 where the incoming RF signal is down converted in frequency to an IF frequency of about 100 MHz by mixing with a local oscillator signal LO1 from local oscillator 28. The signal IF is fed via a gain control unit 29 through a bandpass filter 30 which ensures this receiver is tuned to the frequency of the uplink channel path between PS 10 and LABS 2. The output from bandpass filter 30 is fed to a signal strength detection circuit 32. A switch 34 is provided for feeding the detected IF signal via a further amplifying section 36 to a mixer 38 where it is upconverted by mixing with the signal LO2 from local oscillator 40 to the frequency of the uplink path between LABS 2 and MBS 14. The output signal from mixer 38 is fed via an amplifier 42 to a directional antenna 44 which is a simple yagi having a gain of typically 10 dB.

The signal from RF preamplifier 24 is also fed to a mixer 46, where it is mixed with signal LO2 from local oscillator 40, the output being amplified in a gain control amplifier 48 and filtered in a bandpass filter 50, which ensures this receiver is tuned to the frequencies of the uplink path between adjacent LABS 2NN2, 2NN3 and the MBS. The output of filter 50 is supplied to a signal strength detection circuit 52. A control circuit 54 including a processor is arranged to provide control signals to the circuit particularly switch

34. Output signals from signal strength detectors 32, 52 are digitised at 56, 58 and fed to processor 54.

The general operation of the circuit of Figure 2 is as follows. Signals from PS10 in GSM format are received at antenna 20 and mixed with signal LO1 in mixer 26 to generate signal IF. Signal IF is filtered in first filter 30 to recover uplink transmissions from PS10. If the uplink channel has more than one frequency, then a bank of filters of appropriate size may be provided. Signal strength detection unit 32 estimates the strength of the signal, and this value is digitised and fed to processor 54. If processor 54 determines that the signal strength is above certain levels (see below) processor operates to turn on switch 34 so that the signal IF is upconverted at 38 to the uplink frequency from LABS 2 to MBS 14 (normally a minimum of 10MHz different from the link from PS to LABS) and transmitted via Yagi 44.

The function of bandpass filter 50 (or filter bank) is to detect whether an adjacent LABS has also received the signal from PS10 and is retransmitting the signal on the uplink path. Thus signal strength unit 52 provides an estimate of signal strength to processor 54, which operates in accordance with an algorithm described below, to hold switch 34 open to prevent transmission in appropriate circumstances.

Processor 54 initiates an algorithm to control the LABS. This algorithm incorporates the following general features:-

* Immediate turn on when signal level at LABS up link receiver (I) exceeds, say, -60 dBm.

* Turn off when this signal level falls to below, say, -95 dBm.
* Turn on when signal level rises above -95 dBm and no other LABS transmissions (O) detected prior to completion of its time delay (τ).
* LABS time delays pre-assigned between 1 and 9. Each unit corresponds to, say, 1/9th of a GSM packet duration i.e. 50μs.

The truth table for this operation is as follows:-

* LABS turn on:
  I greater than -60 dBm + $\overline{O}\tau$
* LABS hold: $I\overline{O} + \overline{IO}$ (Second term above holds LABS on in event of DTX operation, but note in the absence of input, ($\overline{I}$), it will not give an output signal, ($\overline{O}$)).
* LABS release: $\overline{I}O$ for two consecutive packets. If it detects $\overline{I}O$ followed by $I\overline{O}$, half rate working is assumed and it treats every alternate frame as an off condition i.e. turn on when $I\overline{O}\tau$ condition identified. Similar operation is assumed for other intermittent control/access transmissions from PSs in that MBS area, which requires that each LABS should be programmed with knowledge of the frame repetitive structures employed.

LABS spacings, uplink receive antenna and receiver sensitivity should be selected so that median signal levels of below, say, -60

dBm are encountered at ranges up to half LABS cell radius and below, say, -80 dBm at full radius.

Each LABS will contain between one to three, up link channels. Each channel will comprise a PS transmit to LABS receive link and a LABS transmit to MBS receive link.

Frequency separations between these two links will be specific to a particular macrocell since each link must conform to the frequency assignments for that cell in both the macrocell and LABS cluster size repeat patterns. A minimum separation of 10 MHz is assumed.

The Macrocell to Static LABS link will be fixed and approximate to a line-of-sight path. Therefore, directional antennas with gain of around 10 dB should be used for this link to minimise LABS transmitter power requirements and enhance link noise margins.

A manually set attenuator may be fitted in the LABS P.A. chain to compensate for the wide variations to MBS received signal level resulting from LABS to MBS spacings ranging from a few hundreds of metres to 20 km.

The antenna for the short range LABS to PS link should take the form of an inverted monopole to provide omni-directional coverage: its radiation pattern will then be shaped to diminish received signal levels at short range (directly below the LABS) and enhance those at longer ranges.

Preliminary estimates demonstrate that the additional phase noise introduced by conventional synthesisers operating as reference frequency sources within the LABS will be acceptable for PCN links operating around 1800 MHz.

The design of the amplifying/filtering elements of the LABS is otherwise conventional.

The preceding presents a rationale for the identification of simple, low cost LABS equipments that can eliminate the asymmetry in path loss capability that is present in Macro Base Station to low power Personal Station duplex radio links.

The design aims:-

1) To identify the simplest, practicable LABS implementation.

2) To minimise the changes required to GSM standard protocols and equipments as a result of introducing LABS into these networks.

CLAIMS

1. A mobile cellular telephone system including a personal or mobile terminal for communicating with a base station and a plurality of local access base stations (LABS) for detecting transmissions from the personal or mobile terminal and relaying the transmissions in an uplink path to the base station, wherein the plurality of LABS are so positioned in relation to a designated area in order that each LABS can detect transmissions from the terminal within the designated area in order to provide diverse paths for relaying detected transmissions to the base station.

2. A telephone system as claimed in claim 1 wherein the terminal is a personal station.

3. A telephone system as claimed in claim 1 wherein the plurality of LABS comprises a multiplicity of LABS, preferably three.

4. A telephone system as claimed in any preceding claim including means for permitting only one of the plurality LABS to relay a detected transmission.

5. A telephone system as claimed in any preceding claim wherein each LABS includes means for detecting transmissions from a personal or mobile stations on a first frequency and retransmitting the detected transmissions on a second frequency.

6. A telephone system as claimed in claim 4 and 5 wherein each of the plurality of LABS provides a carrier signal on the same frequency.

7. A telephone system as claimed in claim 4 and 5 wherein each LABS includes a receiver means for detecting the relaying by another LABS of a terminal transmission to the base station, for inhibiting transmission by the respective LABS, and wherein each LABS includes time delay means for delaying retransmission in response to detection of a terminal transmission by an interval different from that of adjacent LABS.

8. A telephone system as claimed in Claim 4 and 5 wherein each LABS includes means for detecting the strength of a terminal transmission and for retransmitting the terminal transmission in the event the detected signal strength is above a predetermined level.

9. A telephone system as claimed in Claim 8 wherein the signal strength detecting means is arranged to stop retransmissions in the event of the detected signal strength following below a predetermined level.

10. A telephone system as claimed in claim 6 wherein the LABS is arranged to remain on in the event of half rate, or any other intermittent working permitted within the system protocol.

11. A mobile cellular telephone system substantially as described with reference to the accompanying drawings.

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